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Aggregate Resources Inventory of the Township of Zorra

Oxford County

Southern Ontario

by Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey

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Aggregate Resources Inventory of the Township of Zorra Oxford County

by Staff[1] of the Engineering and Terrain Geology Section

1. Project Supervisors: Dale W. Scott and I. Szoke; field work and report by J.L. Watson and E. Garnet; compilation and drafting by Staff of the Aggregate Assessment Office. The Mineral Resources Staff of Aylmer District and Southwestern Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Abstract

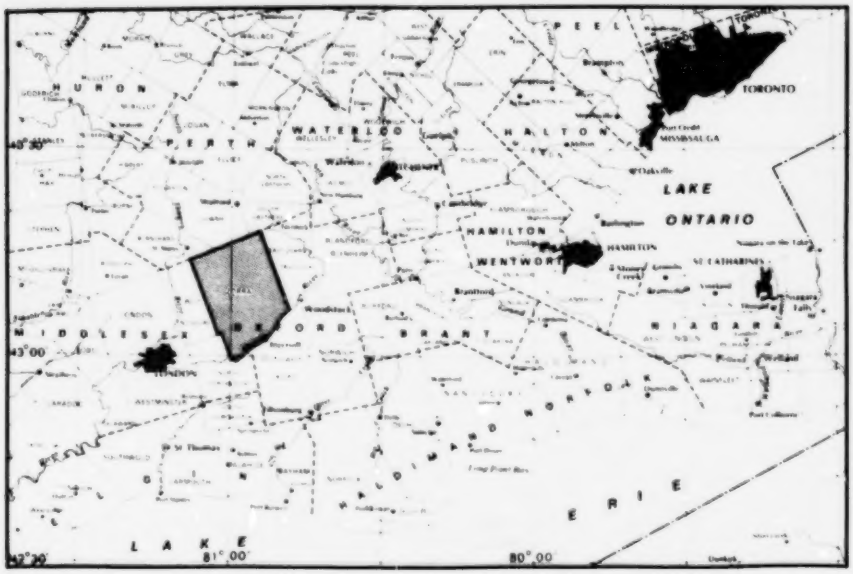


Figure 1. *Key Map Showing the Location of the Township of Zorra, Scale 1:1 800 000.*

This report includes both an inventory and analysis of sand and gravel as well as bedrock resources in the Township of Zorra. The report is part of the Aggregate Resources Inventory Program for townships and municipalities designated under the Pits and Quarries Control Act.

Three groups of sand and gravel deposits have been suggested for possible resource protection and/or development at the primary level of significance. One group is ice-contact stratified drift associated with an ice-marginal position in the northern part of the township; the other two groups are outwash deposits belonging to the meltwater channels of Mud Creek and the Thames River. These deposits contain good-quality material with few quality constraints. The three primary areas occupy a total of 5300 acres (2140 ha), exclusive of licenced properties. An estimated 4300 acres (1740 ha) are currently available, containing approximately 280 million tons (255 million tonnes) of aggregate acceptable for a range of granular base course and hot-laid asphalt products.

In addition, a number of sandy ice-contact stratified drift and gravelly outwash deposits have been selected at the secondary level of significance. This material also should be considered as part of the township's total aggregate supply.

The surficial deposits are underlain by limestone and dolostone of the Lucas and Amherstburg Formations of the Detroit River Group and limestone of the Dundee Formation. Limestone of the Lucas Formation is of particular value for extraction because of its high purity, uniformity and thickness. A large area of the Lucas Formation in the south-central part of the township has been selected for possible resource protection. Total resources, excluding the licenced properties are estimated to be 3900 million tons (3550 million tonnes). The limestone is acceptable for the manufacture of flux stone, chemical lime, portland cement, agricultural lime, fillers, and minor crushed stone. The Dundee Formation limestone also has economic value, but does not warrant the removal of the excessive drift cover.

Selected Resource Areas are not intended to be permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1984, the total tonnage of mineral aggregates extracted was 109 million tons (99 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Weatherson 1986).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11- to 45-kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases Los Angeles abrasion, absorption, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications, or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size, and depth of extraction of pits licenced under the Pits and Quarries Control Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g. wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of uncon-

solidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor (the estimated weight in tons of a one-foot (0. 3 m) thick section of rock, one acre (0.4 ha) in extent).

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg per cubic metre) or 3600 tons per acre (8070 tonnes per hectare). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg per cubic metre) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg per cubic metre).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (see Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

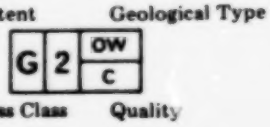
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, all sand and gravel deposits are outlined and shaded. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Map 1. These components are illustated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary; secondary; and tertiary. Each area of primary significance is assessed as to its probable relative value as a resource in the municipality and is given a deposit number which denotes its ranking order. All such deposits are shown by dark shading on Map 2.

Deposits of secondary significance are not ranked numerically in this report, but are indicated by

light shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quanitities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

Selected Sand and Gravel Resource Areas of primary significance are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 (greater than 20 feet (6 m) thick), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications (M.T.C.) and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of M.T.C. quality tests are listed by test type and sample location. The types of tests conducted and the test specifications are explained in Appendices B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; Hot-Laid Asphaltic Sand Nos. 1,2,3,4, and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for

each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalites with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three levels of shading. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas consitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Pits and Quarries Control Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be described further in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation and Communications. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units which must be incorporated in an official planning document. They represent areas in which a major bedrock resource is known to exist. Such Resource Areas may be reserved wholly or partially for extractive development and/or resource protection within the context of the official plan.

Part III — Assessment of Aggregate Resources in the Township of Zorra

LOCATION AND POPULATION

The Township of Zorra occupies an area of 127,292 acres (51 515 ha) in northwestern Oxford County. The township is shown mainly on the Woodstock (40 P/2), but also on the Lucan (40 P/3), Stratford (40 P/7), St. Marys (40 P/6) and Tillsonburg (40 I/15) map sheets of the National Topographic System at a scale of 1:50 000.

The total population of the township, exclusive of urban areas, was 8,060 in 1985, an increase of approximately 13 percent since 1973 (Ontario Ministry of Municipal Affairs 1986; Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1974). The Town of Ingersoll, part of which is located on the southern boundary of the township, had a population of 8,469 in 1985 (Ontario Ministry of Municipal Affairs 1986). Ingersoll is a regional trade and retail centre. Smaller communities within the township include Thamesford, Embro, Lakeside, Harrington West, and Kintore.

Road access is provided by King's Highways 2, 7 and 19, as well as by paved county and gravel-surfaced township roads. Access is also provided by two lines of the Canadian Pacific Railway, one of which runs through Lakeside and Embro and south to Zorra, where it meets the second line which runs east-west through Thamesford. A line of the Canadian National Railways runs along the southern boundary of the township through Ingersoll and Beachville.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The Township of Zorra has a gently rolling and undulating topography with local relief rarely exceeding 50 feet (15 m). The surface is broken by several features, such as hummocky end moraines and kames. Erosional features include the deeply incised meltwater channels now occupied by Mud Creek and the Thames River. The physiography and land use activities are further described by Chapman and Putnam (1984, pp. 143-144). The reader is specifically referred to their discussion of the Oxford Till Plain physiographic region.

In brief, the current landscape and distribution of surficial materials are the result of the advance and melting back of massive, continental ice sheets. The most significant glacial events occurred approximately 23 000 to 14 000 years ago during the Late Wisconsinan Substage of the Pleistocene Epoch (the 'Great Ice Age'). Cowan (1975), Sado (1980a, b), and others have described in detail the geological history of their respective map areas. The following discussion of the geological history of the Township of Zorra draws primarily upon their work.

About 16 000 to 18 000 years ago, the initial advance of the Late Wisconsinan ice resulted in the deposition of Catfish Creek Till throughout most of southwestern Ontario, including the Township of Zorra. This coarse-textured and stony till is exposed at the subsurface on the Dorchester Moraine to the south of Thamesford. The stony nature of the Catfish Creek Till made it favourable for reworking by meltwaters into gravels of suitable size. Consequently, the till is often found in association with glaciofluvial sands and gravels of economic value (Cowan 1975, p. 23). A good example is the gravelly outwash deposit in southeast Zorra which has been selected as a primary resource area.

After a period of glacial retreat during which large proglacial lakes laid down mantles of sand, silt and clay, the ice readvanced from the Lake Erie basin in a northwesterly direction. This Erie lobe overrode the earlier tills and lacustrine sediments and deposited several layers of material known as the Port Stanley Till - a brown to dark brown, silt to clayey silt till with a low clast content (Barnett 1982). Cowan (1975, p. 24) suggests that this till may be present as far west as Embro. However, the fine-grained nature of the Port Stanley Till makes it unacceptable for any granular use.

While the Port Stanley Till was being deposited in the southeast part of the township, glacial ice moving southeast from the Lake Huron basin was depositing the Tavistock Till which covers much of the township. This till (informally termed the Zorra till by Cowan 1975) is a stony, silt or sandy silt till occurring as ground moraine or in drumlins (Cowan 1975, p. 28). An older, subdued feature - the Dorchester Moraine - was overridden by the ice and covered by Tavistock Till. The till overlying the moraine is interlain with layers of sand and gravel. However, the till, itself, is an unsuitable source of aggregate because of its high fines content.

The margins of the Huron and Erie ice lobes were in confluence at the Ingersoll Moraine to the south of the Thames River. Gradual melting back from the interlobate zone resulted in vast amounts of meltwater flowing westward in a deeply incised channel now occupied by the Thames River. The outwash material deposited by the combined runoff from the two ice lobes may cover a larger area than is indicated by present Quaternary mapping. A recent study by Sado (1980b) in neighbouring North Dorchester Township suggests that granular deposits from 50 to 75 feet (15 to 23 m) thick may underlie much of the surface. The quality of the aggregate is undetermined, although Sado (1980b, p. 8) believes a figure of 10 to 25 percent fine gravel would be reasonable. Cowan (1975, p. 40) describes the terrace deposits of the Thames River (South Branch) north of Ingersoll as occupying a narrow strip between the present floodplain and the walls of the meltwater channel. He describes the material as mainly pebbly fine sand with only local occurrences of gravel suitable for aggregate. These characteristics also pertain to the Mud Creek meltwater channel. Along the Thames River (Middle Branch) the channel is less confining and the well terraced outwash deposits cover a larger area. Some of these deposits may be deltaic in origin (Cowan 1975, p. 40).

As the Huron lobe continued to retreat from the Ingersoll Moraine, small proglacial lakes developed against the ice margins, accompanied by deposition of glaciofluvial and glaciolacustrine material. During the formation of these lakes, Sado (1980a, p. 94)

states that the ice appears to have been partially afloat forming an ice shelf. Large quantities of ice-contact stratified drift were deposited subaqueously beneath these ice shelves. The ice-contact zones of the Cobble Hills, Lakeside and Harrington West areas can be attributed to this process. These areas consist of sandy kames rising to 100 feet (30 m) above the surrounding till plain in the Cobble Hills area. Although the material is predominantly sandy and interspersed with Tavistock Till, the kame hills may contain gravel pockets suitable for aggregate extraction. This is particularly the case in the Lakeside and Harrington West areas (Cowan 1975, p. 41).

The eventual draining of the glacial lakes marked the end of glacial activity in the area. Geological processes of recent times have been of minor importance in modifying the landscape of the township.

EXTRACTIVE ACTIVITY FOR SAND AND GRAVEL

A total of fifty-three sand and gravel pits were identified in the Township of Zorra. At present, twenty-four of the pits are licenced to operate under the Pits and Quarries Control Act. The licenced properties have a total area of 1341.5 acres (542.9 ha) and are located in outwash or ice-contact deposits associated with the Lake Huron and Erie ice lobes.

Deike (1981) has summarized the more important quality factors and pit workability conditions which are applicable to these sand and gravel deposits. In brief, these are:

1. Chert content - Particularly in the outwash deposits, the high percentage of chert, which ranges from 3 to 20 percent, is the main problem. Beneficiation measures are required for higher-quality aggregate products.
2. Crushable size gravel - Outwash deposits contain adequate supplies. Where percentages do not meet specification requirements, selective extraction and sand control will be necessary.
3. Depth and uniformity of deposits - Coarse gravel deposits are generally deep and uniform, which increases long-term extraction efficiency. Sand or silt seams are not common.
4. Percent oversize material - Oversize material, present in many of the outwash deposits, may be crushed to increase the quality of the deposit.
5. Percent coarse sand - Coarse sand is a common occurrence. This material is less stable in an aggregate mix than finer sand and tends to be of poorer quality.
6. Depth of overburden - Overburden depths are not excessive and average 0.5 to 1 foot (0.2 to 0.3 m).
7. Depth to water table - Water table levels are normally not a problem.
8. Percent fines - Excess fines in area sands are not a common occurrence.

Total production figures for licenced sources have been compiled annually by the Aylmer District Office of the Ontario Ministry of Natural Resources since designation of the township in 1975 under the Pits and Quarries Control Act. The average annual production of sand and gravel between 1976 and 1981 was 457,536 tons (415 077 tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 indicates the deposits which contain granular materials. Many of these potential resources have limited value for reasons of deposit size, thickness or quality of the material. Consequently, only the most significant sources have been suggested for development and/or protection at the primary level.

Each of the three areas of primary value are made up of several deposits which have similar modes of origin. These are the Harrington West ice-contact deposits, the Mud Creek and Thames River (Middle Branch) outwash, and outwash associated with the confluence of the Thames River Middle and South Branches. The interpretation of existing geological data indicates that the primary areas contain good-quality sand and gravel in comercial quantities.

The primary areas total 5300 acres (2140 ha), exclusive of licenced properties. Approximately 4300 acres (1740 ha) are currently available for development and/or protection. Total aggregate resources are estimated to be 280 million tons (255 million tonnes), or 25 percent of the original tonnage.

Resources selected at the secondary level include sandy ice-contact material of the Lakeside and Cobble Hills areas and several gravel outwash deposits belonging to the above meltwater channels. Although deposits selected at the secondary level are not the "best" sources, they should nevertheless be considered as part of the township's aggregate supply.

SELECTED SAND AND GRAVEL RESOURCE AREA 1

Selected Sand and Gravel Resource Area 1 is made up of six deposits of ice-contact stratified drift which are located near Harrington West in the northern part of the township. Cowan (1975, p. 41) believed that the sediments were deposited at or near an ice margin and represent a period of stagnant ice with considerable subglacial drainage. Although the sediments are mainly fine sand interspersed with till, coarse gravel and sand are available in commercial quantities in a number of knolls and kames.

The sand and gravel pits for the most part are located in these gravelly knolls and kames. There are ten licenced and four unlicenced properties in the resource area (pit nos. 1 to 4, 6 to 10, 12, 25, 28, 29 and 31). Face heights and gravel contents vary considerably from site to site. For example, pit faces in Area 1a range from 15 to 75 feet (5 to 23 m) and gravel contents from 35 to greater than 60 percent. Test hole data obtained from the Ontario Ministry of Transportation and Communications (M.T.C.) and analyzed by Deike (1981) show that the pits in the resource area contain coarse sand and gravel beds 6 to 11 feet (2 to 3 m) deep and are relatively free of fine sandy lenses. Several of the test holes reported coarse granular material with a gravel content in excess of 75 percent.

The gravel knolls in Area 1 are easily extracted and contain material with fairly uniform distribution. There are also few quality constraints. Chert content here is the lowest in the township, averaging 5 to 10 percent. Although oversize material is present, it is acceptable for crushing. Consequently, the granular material is suitable for a range of aggregate products including Granular Base Course (G.B.C.) A, B and C, 16 mm crushed Type A and Hot-Laid (H.L.) No. 4 stone. The coarse sands require blending for hot-laid sand.

Resource Area 1 totals 1420 acres (580 ha), exclusive of the licenced properties. Deletions for setbacks and previous extraction reduce the area available to 1110 acres (450 ha). Aggregate resources are estimated to be 68 million tons (62 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 2

Selected Sand and Gravel Resource Area 2 consists of six outwash deposits associated with the Thames River (Middle Branch) and Mud Creek meltwater channels. Mud Creek deposits occur as isolated sand and gravel terraces about 10 to 75 feet (3 to 23 m) above the present-day floodplain. The sediments are generally less than 25 feet (8 m) thick and exhibit southwesterly dipping crossbeds lying parallel to the direction of glacial stream flow (Cowan 1975, p. 40). The Thames River (Middle Branch) deposits are well terraced and may be deltaic (Cowan 1975, p. 40)

There are three licenced properties (pit nos. 14, 15 and 17) and three unlicenced properties (pit nos. 39, 43 and 45) located within the terrace deposits. The gravels are poorly to well sorted and vary from coarse cobbly gravel to fine pebble gravel and gravelly sand. The coarser aggregate averages 6 to 12 feet (2 to 4 m) in depth. The sands also range from very coarse to fine with similar variations in sorting. Excavations in the three licenced properties range from 15 to 55 feet (5 to 17 m). The gravel content ranges from 50 to 80 percent. Face heights and gravel percentages are lower in the smaller unlicenced properties.

Test data show a moderate to high chert content of 5 to 15 percent, although the content may vary from pit to pit. Generally, data obtained from Magnesium Sulphate and Los Angeles Abrasion Tests prove that the material is acceptable for high-quality coarse aggregate uses (Deike 1981).

Resource Area 2 totals 1020 acres (415 ha), exclusive of the licenced pits. Deletions for setbacks and previous extraction reduce the area currently available to 860 acres (350 ha). Aggregate resources in Area 2 are estimated to be 52 million tons (47 million tonnes).

SELECTED SAND AND GRAVEL RESOURCE AREA 3

Selected Sand and Gravel Resource Area 3 represents five outwash deposits located close to the confluence of the Thames River Middle and South Branches. Here, the channels are less confining and the terraces are spread over a wider area. Cowan (1975, p. 40) mentions that some of the material may be deltaic in origin, although this possibility was not investigated during the field study.

Areas 3a, b and c contain parts of the Dorchester Moraine - a complex feature, composed of up to 12 feet (4 m) of sandy Tavistock Till overlying older sand and gravel interlain with layers of till (Sado 1980a, p. 71). Other parts of the deposit are till free and have little or no overburden. Field examination of pits in the North Dorchester portions revealed a high degree of variability with crushable aggregate occurring in pockets. The aggregate is largely medium to coarse gravel mixed with medium to coarse sand and has an overall gravel content in the range of 50 to 80 percent. The gravel content decreases to 30 to 65 percent towards the north. Pit no. 46 in Area 3a is fairly characteristic, with a 20- to 30-foot (6 to 9 m) face height and a gravel content of 50 to 70 percent.

The remaining parts of Area 3 contain material similar to that in the deposits of Area 2. However, in Area 3, the coarser aggregate has a thinner bedding of 5 to 6 feet (1.5 to 2 m) and is often intermixed with silt and thin sandy seams (Deike 1981, p. 17). Areas 3d and 3e contain seven licenced properties (pit nos. 18 to 24) with face heights ranging from 5 to 40 feet (1.5 to 12 m) and gravel contents from 5 to 65 percent. There are, in addition, six unlicenced properties (pit nos. 46, 48 to 52) which have slightly lower face heights and gravel percentages.

The gravels are satisfactory for crushing provided greater than 1 inch (2.5 cm) material is available and silty and sandy sections are avoided. The material is suitable for G.B.C. A and H.L. 4 surface paving aggregate, the latter with selective screening and sand control. The sand fractions grade coarse and dirty and blending is required for hot-laid asphalt products. Minor cementation may also be a problem where the aggregate is overlain by till (Barnett 1982, p. 51). Chert is also present in the deposits.

Resource Area 3 totals 2900 acres (1170 ha), exclusive of the licenced properties. Approximately 2310 acres (940 ha) are currently available, containing resources of 162 million tons (147 million tonnes).

SAND AND GRAVEL RESOURCE AREAS OF SECONDARY SIGNIFICANCE

Several outwash and ice-contact deposits are suggested for possible development and/or protection at the secondary level of significance. Many of these deposits contain pits from which useful granular material has been extracted. Consequently, these deposits should be considered as part of the township's aggregate supply.

The ice-contact stratified drift includes the Lakeside and Cobble Hills deposits as well as four deposits in the northwest corner of the township and one in the vicinity of Brooksdale. The sediments are variable and may range from till to sorted gravel, sand or clay. For example, the northernmost portion of the Lakeside deposit (adjacent to Area 1a) contains bouldery gravels which become finer grained and better sorted toward the village of Lakeside. There are five unlicenced properties (pit nos. 32 to 36) in the secondary part with face heights ranging from 5 to 50 feet (1.5 to 15 m). The gravel content is

generally less than 10 percent. Deike (1981) comments that the material is satisfactory for most sand requirements and that, at present, little of this resource has been exploited. In contrast, coarser ice-contact material has been extracted near Brooksdale in licenced pit no. 11. Here, the faces are 20 to 30 feet (6 to 9 m) high and contain aggregate with a gravel content of 50 percent. Data obtained from M.T.C. indicated that the aggregate is acceptable for select subgrade material and G.B.C. B and C. The remaining ice-contact deposits are mainly sand sources with very little crushable material.

The outwash deposits are associated with the glacial meltwater channels described earlier. These deposits are small, gravelly terraces similar in composition to the primary areas. For example, one of the terraces at Thamesford contains coarse sand and gravel as exposed in the 25- to 30-foot (8 to 9 m) faces of pit no. 47. This pit is capable of producing G.B.C. A, H.L. 4 and higher quality stone products (Deike 1981). Pit no. 42 also contains crushable material, although in more limited quantities. Deike (1981) describes the deposit as variable and the aggregate acceptable for G.B.C. A.

BEDROCK GEOLOGY

The bedrock surface of the Township of Zorra is flat to gently rolling with a gradual slope to the south. Throughout most of the township drift thickness is considerable, ranging from 50 to greater than 200 feet (15 to 61 m). In the Thames River (South Branch) valley, drift is less than 50 feet (15 m) thick.

The oldest bedrock unit is the Detroit River Group. This group underlies roughly two-thirds of the township and can be divided into two lithologically similar but chemically different formations - the Lucas and Amherstburg Formations. To the southeast of Embro, the Detroit River Group is mainly limestone; to the northwest, limestone and dolostone facies interfinger until at St. Marys (Blanshard Township) the unit is mainly dolostone. The limestone facies, of particular interest in this report, consists of 100 to 110 feet (30 to 34 m) of high-purity calcium limestone, medium brownish grey to tan in colour, medium-crystalline to microcrystalline in texture, medium to thick bedded, with abundant corals and stromatoporoids (Hewitt and Vos 1972, p. 63). The Lucas Formation is the thickest, most uniform and purest high-calcium limestone available in Ontario (Hewitt and Vos 1972).

Because of its thickness, uniformity and high quality, the limestone of the Lucas Formation is quarried mainly for the production of lime and flux stone, as well as agricultural lime, fillers and minor crushed stone at Beachville and portland cement at Zorra. Because of its importance as an industrial mineral, a large area of Lucas Formation, overlain by up to 100 feet (30 m) of drift, has been selected for possible resource protection. Although parts of the resource area are overlain by great thicknesses of drift, the high value of the limestone may warrant the removal of such quantities of overburden. This is the case at the Canada Cement Lafarge Ltd. quarry (quarry no. 1).

The Detroit River Group is overlain to the southwest by the Dundee Formation. This formation ranges in thickness from 60 to 160 feet (18 to 49 m) and consists of light brown, medium-grained limestone with some chert present (Hewitt 1972, p. 12). The limestone is quarried at St. Marys for the manufacture of portland cement and elsewhere in southwestern Ontario for crushed stone. In the Township of Zorra, however, drift cover varies from 50 to over 100 feet (15 to 30 m). Consequently, quarry activities for this rock are uneconomical.

EXTRACTIVE ACTIVITY FOR BEDROCK

Substantial extraction of the Lucas Formation limestone has taken place in the Township of Zorra. At present, 3241.4 acres (1311.8 ha) are licenced by four operators. Quarry nos. 2, 3 and 4 are located between Ingersoll and Beachville in the Thames River valley. Quarry no. 1 is located to the north, along King's Highway 2.

Total production, compiled by the Aylmer District Office, Ministry of Natural Resources, between 1976 and 1981 was 3,325,332 tons (3 016 741 tonnes). The majority of the stone quarried by quarry nos. 2, 3 and 4 was used to produce metallurgical flux stone and chemical lime. Limestone extracted by Canada Cement Lafarge Ltd. (quarry no. 1) was used in the manufacture of grey portland cement. In addition to this cement plant, Federal White Cement Ltd. utilizes local limestone to produce white portland cement.

In addition to the limestone bedrock, Canada Cement Lafarge Ltd. also utilizes the glacial overburden at quarry no. 1. Over 165,000 tons (150 000 tonnes) of clay removed from the glacial overburden are used annually in the cement manufacturing process (B.H. Feenstra, Mineral Resources Geologist, Ontario Ministry of Natural Resources, London, personal communication, 1982).

SELECTED BEDROCK RESOURCE AREA 1

Selected Bedrock Resource Area 1 occupies a large area in the Thames River valley, and between Ingersoll and Embro. Here, bedrock of the Lucas Formation is overlain by less than 100 feet (30 m) of drift. Along the Thames River valley east of Ingersoll, the formation has been exposed by the action of glaciofluvial erosion. This is the main area of quarrying operations in the township and where three of the four licenced properties are located (quarry nos. 2, 3 and 4). The quarries have been extensively worked for the high-purity, calcium limestone which has been used for the production of flux stone, chemical lime, agricultural lime, fillers and minor crushed stone.

Hewitt (1960, pp. 155-158) described one of these quarries (quarry no. 4, Steel Co. of Canada Ltd.). At the time of his examination, a 100- to 110-foot (30 to 34 m) section of high-purity limestone was exposed. About 15 feet (5 m) of sandy limestone overlies the high-purity material. This cap rock is relatively impure and must be stripped prior to quarrying. The underlying material consisted of medium brown to light tan, medium-crystalline to microcrystalline, thick-bedded limestone with black shaly partings

(Hewitt 1960, p. 156). Diamond drill hole tests indicated the limestone beds were about 104 feet (32 m) thick. Their composition was documented by Hewitt (1960, p. 156).

Bedrock Resource Area 1 has an area of 12,400 acres (5000 ha), exclusive of the licenced properties. Deletions for cultural setbacks reduce the area available to 10,900 acres (4400 ha). Assuming an average workable thickness of 100 feet (30 m), total limestone resources are 3900 million tons (3550 million tonnes).

Because of the high costs involved in stripping overburden, the parts of Bedrock Resource Area 1 overlain by less than 50 feet (15 m) of drift are the most desirable for resource development. However, the high chemical purity and resulting high value of the Lucas Formation may warrant the expense of removing greater thicknesses of overburden (as at quarry no. 1). Because of the great costs involved in stripping the overburden, thorough testing of the bedrock should be performed to ensure its quality prior to the commencement of extraction operations.

SUMMARY

The sand and gravel deposits of the Township of Zorra are mainly the product of glacial activity which occurred during the "Great Ice Age". The primary resources consist of a number of ice-contact and outwash deposits grouped into three areas. The primary areas contain good-quality sand and gravel with very few quality constraints. The secondary areas also include ice-contact and outwash deposits which contain a variety of materials and add to the township's total aggregate supply.

Three bedrock formations underlie the surficial materials. High-purity, calcium limestone of the Lucas Formation has been extensively quarried in the Beachville-Ingersoll area for the production of flux stone, chemical lime, portland cement, agricultural lime, fillers and minor crushed stone. A large area in the south-central part of the township has been suggested for resource protection and/or development. The drift cover in this area is relatively thick, however, the value of the Lucas Formation limestone may warrant the removal of such thicknesses of overburden. Limestone of the Dundee Formation, although acceptable for the manufacture of portland cement, is thickly drift-covered and does not have the uniformity or value of the Lucas Formation.

Enquiries regarding the Aggregate Resources Inventory of the Township of Zorra should be directed to the Aggregate Assessment Office, Ontario Geological Survey, Ministry of Northern Development and Mines, Room M1B-45, Macdonald Block, Queen's Park, Toronto, M7A 1W4 (Tel. (416) 965-1663), or to the Ontario Ministry of Natural Resources either at the Aylmer District Office, 353 Talbot Street West, Aylmer, Ontario, N5H 2S8 (Tel. (519) 773-9241) or at the Southwestern Region Geological Office, 458 Central Avenue, London, Ontario, N6B 2E5 (Tel. (519) 433-8431).

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, TOWNSHIP OF ZORRA*.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
1	G-IC	1500 (610)	107 (97)
	G-OW	3500 (1420)	255 (231)
	S-IC	3100 (1260)	155 (141)
	S-OW	385 (156)	20 (18)
2	G-IC	610 (247)	28 (25)
	G-OW	2700 (1090)	115 (104)
	S-IC	2550 (1030)	94 (85)
	S-OW	7700 (3100)	280 (255)
3	G-IC	180 (73)	4 (4)
	G-OW	220 (89)	5 (4)
	S-AL	4 (2)	<1 (<1)
	S-IC	480 (194)	11 (10)
	S-LP	750 (305)	11 (10)
	S-OW	140 (57)	2 (2)
4	G-IC	56 (23)	<1 (<1)
	G-OW	4 (2)	<1 (<1)
	S-AL	236 (96)	2 (2)
	S-IC	132 (53)	1 (1)
	S-LP	630 (255)	6 (5)
	S-OW	152 (62)	2 (2)
		25,000 (10 100)	1100 (1000)

N.B. Minor variations in all tables are caused by rounding of data.

*Identified deposit areas within the Town of Ingersoll have been omitted on all tables.

TABLE 2. SAND AND GRAVEL PITS, TOWNSHIP OF ZORRA.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
LICENCED PITS							
1	S11-008	J. Tanner Const. Ltd.	E-1/2 35	3	25.0 (10.1)	15-20 (5-6)	60
2	-	Corp. of the Twp of Downie	W-1/2 34	3	70.5 (28.5)	10-30 (3-9)	60
3	S11-089	Harrington Sand & Gravel	E-1/2 32&33	2	110.0 (44.5)	20-35 (6-11)	40-60
4	S11-78	Yundt Bros. Const. Ltd.	Pts.32 &33	3	175.0 (70.8)	30-50 (9-15)	30-35
5	L07-042	Carolus H. Pelkmans	Pt. 29	8	20.5 (8.3)	15 (5)	25
6	L7-43	K and H Sand & Gravel	NE-1/2 28	14	54.0 (21.8)	20-40 (6-12)	60
7	L07-193	T.C.G. Materials Ltd.	W-1/2 29	1	84.0 (34.0)	30-40 (9-12)	60
8	L7-81	T.C.G. Materials Ltd.	NW-1/4 28	1	54.0 (21.8)	20-30 (6-9)	60
9	L07-081	Townline Sand & Gravel	SW-1/4 28	1	46.0 (18.6)	60-75 (18-23)	45
10	W11-078	T.C.G. Materials Ltd.	E-1/2 28	1	50.0 (20.2)	30 (9)	35-45
11	W11-033	Grant Innes	SE-1/4 28	4	7.2 (2.9)	20-30 (6-9)	50
12	W11-082	John Alexander	Pt.26	5	106.0 (42.9)	15-25 (5-8)	60
13	W11-135	Lewis J. Pelton	E-1/2 20	3	33.5 (13.6)	45-65 (14-20)	30-60
14	W11-084	Masson Sand & Gravel	W-1/2 10	6	103.9 (42.0)	40-55 (12-17)	70
15	W11-003	George Totten	NE-1/2 7, SE -1/4 8	4	102.5 (41.5)	15-20 (5-6)	50-60
16	-	Corp. of the Twp. of Zorra	E-1/2 6	3	4.5 (1.8)	10-15 (3-5)	60
17	W11-156	Beaty Farms Ltd.	W-1/2 3	11	98.0 (39.7)	30-40 (9-12)	70-80
18	W11-027	Corp. of the Twp. of Zorra	Pt.24	4	10.0 (4.0)	5-10 (1.5-3)	50-60
19	W11-047	J.W. Thompson Const. Ltd.	Pt.23	5	15.0 (6.1)	5-25 (1.5-8)	30
20	-	542019 Ontario Ltd.	Pt.23	5	20.0 (8.1)	15-25 (5-8)	30

TABLE 2. SAND AND GRAVEL PITS, TOWNSHIP OF ZORRA.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
21	W11-123	Walmsley Bros. Ltd.	Pt.24	5	23.7 (9.6)	30-40 (9-12)	45-65
22	-	Beaty & Beaty Ltd.	Pt.24	5	35.7 (14.4)	10-30 (3-9)	5
23	W11-157	J.A. Pierce Ltd.	N-1/2 2	5	51.0 (20.6)	20-25 (6-8)	45-60
24	-	J.A. Pierce Ltd.	S-1/2 2	5	41.5 (16.8)	25 (8)	45-60
					1341.5 (542.9)		
UNLICENCED PITS*							
25	S11-70	Bartlett	33	3		20 (6)	60-70
26	L07-091	Forbes No. 1	33	13		10-15 (3-5)	50
27	L07-041	Waugh	30	8		15 (5)	10
28	L07-043	Otto Rounds	28	14		25-35 (8-11)	60
29	L07-093	Ella Kittmer	28	1		30-40 (9-12)	50
30	W11-125	McIntosh	30	3		15-20 (5-6)	10
31	W11-079	Clark	27	1		15 (5)	40-50
32	-	Clarence Rounds	26	13		10-30 (3-9)	10
33	-	unknown	23	12		10-25 (3-8)	10
34	L07-130	Pickering	23	12		40-50 (12-15)	10
35	L07-129	Howard Worte	22	11		10-25 (3-8)	10
36	L07-82	Bryant	21	13		5-20 (1.5-6)	10
37	W11-097	Blair	16	8		10-15 (3-5)	20
38	L07-131	Lorne Logan	14	8		15-20 (5-6)	30
39	W11-146	Mason Sand & Gravel	10	6		20-25 (6-8)	50
40	W11-086	L.H. Dunham	8	5		6-15 (2-5)	20
41	-	C. Moyer	6	3		20 (6)	30

*Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 2. SAND AND GRAVEL PITS, TOWNSHIP OF ZORRA.

1 No.	2 MTC No.	3 Owner/ Operator	4 Lot	5 Con.	6 Licenced Areas Acres (Hectares)	7 Face Height Feet (Metres)	8 % Gravel
42	W11-081	Fleming	6	2		10-15 (3-5)	45-50
43	-	G. Mitchell	7	13		4-12 (1-4)	30
44	-	P. Baldwin	8	13		5-20 (1.5-6)	50
45	W11-021	McCready	5	12		10-15 (3-5)	45-50
46	L07-044	L. Wilson	19,20	1		20-30 (6-9)	50-70
47	W11-080	Golding	23	1		25-30 (8-9)	30
48	W11-135	Pelton	21	3		5-20 (1.5-6)	60
49	L07-074	R. Leslie	19	3		5-10 (1.5-3)	30
50	W11-068	Olive Bartindale	23	4		15 (5)	30
51	W11-126	Pirie	1	5		20 (6)	35
52	W11-121	N. Oxford Twp.	24	5		10-15 (3-5)	50
53	-	unknown	14	3		10-15 (3-5)	35

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, TOWNSHIP OF ZORRA.

1 Deposit No.	2 Unlicenced Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
1a	350 (142)	100 (40)	5 (2)	245 (99)	30 (9)	18 (16)
1b	275 (111)	30 (12)	5 (2)	240 (97)	25 (8)	15 (14)
1c	40 (16)	10 (4)	0 (0)	30 (12)	15 (5)	1 (1)
1d	355 (144)	55 (22)	0 (0)	300 (121)	25 (8)	19 (17)
1e	400 (162)	100 (40)	0 (0)	300 (121)	20 (6)	15 (14)
	1420 (580)	295 (119)	10 (4)	1110 (450)		68 (62)
2a	325 (132)	50 (20)	5 (2)	270 (109)	30 (9)	20 (18)
2b	200 (81)	20 (8)	0 (0)	180 (73)	25 (8)	11 (10)
2c	250 (101)	40 (16)	10 (4)	200 (81)	20 (6)	10 (9)
2d	175 (71)	25 (10)	0 (0)	150 (61)	20 (6)	8 (7)
2e	70 (28)	10 (4)	0 (0)	60 (24)	20 (6)	3 (3)
	1020 (415)	145 (59)	15 (6)	860 (350)		52 (47)
3a	470 (190)	100 (40)	10 (4)	360 (146)	30 (9)	27 (24)
3b	240 (97)	40 (16)	0 (0)	200 (81)	30 (9)	15 (14)
3c	1220 (495)	220 (89)	0 (0)	1000 (405)	30 (9)	75 (68)
3d	370 (150)	60 (24)	10 (4)	300 (121)	15 (5)	11 (10)
3e	600 (243)	140 (57)	10 (4)	450 (182)	30 (9)	34 (31)
	2900 (1170)	560 (227)	30 (12)	2310 (940)		162 (147)
	5300 (2140)	1000 (405)	55 (22)	4300 (1740)		280 (255)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, TOWNSHIP OF ZORRA.

1 **DRIFT THICKNESS** Feet (Metres)	2 **FORMATION**	3 **ESTIMATED DEPOSIT THICKNESS** Feet (Metres)	4 **AREAL EXTENT** Acres (Hectares)	5 **ORIGINAL TONNAGE** Millions of Tons (Tonnes)
25-50 (8-15)	Dundee	60 (18)	40 (16)	9 (8)
50-100 (15-30)	Dundee	60 (18)	13,600 (5500)	2950 (2700)
			13,600 (5500)	2950 (2700)
25-50 (8-15)	Lucas (Detroit River Group)	100 (30)	2200 (890)	790 (720)
50-100 (15-30)	Lucas (Detroit River Group)	100 (30)	11,600 (4700)	4200 (3800)
			13,800 (5600)	5000 (4550)
50-100 (15-30)	Amherstburg (Detroit River Group)	100 (30)	255 (103)	92 (83)
			27,500 (11 100)	8000 (7300)

TABLE 5. QUARRIES, TOWNSHIP OF ZORRA.

1 NO.	2 MTC NO.	3 OWNER/ OPERATOR	4 LOT	5 CON.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)
LICENCED QUARRIES						
1	W11-124	Canada Cement LaFarge Ltd.	Pts. 2, 3,4,5	2	1400.0 (566.6)	100 (30)
			Pts. 2, 3,4	3		
			Pts. 1, 2,3	4		
2	W11-091 W11-029	Domtar Chemicals Ltd.	Pts. 17, 18	1	590.0 (238.8)	65 (20)
			Pts. 17, 18	2		
			Pt. 17	3		
3	W11-073 W11-060	Beachvilime Ltd.[1]	Pt. 17, 18	2	530.4 (214.7)	80 (24)
			Pts. 15, 16,17	3		
4	W11-070	Steel Co. of Canada Ltd.[1]	Pts. 14, 15	2	721.0 (292.0)	50 (15)
			Pts. 14, 15	3		
			Pts. 13, 14	4		
					3241.4 (1311.8)	
UNLICENCED QUARRIES[2]						
			-NONE-			

[1]The quarry licences held by these companies include additional licenced acreage in the adjacent Township of South-West Oxford which are not included in this table.

[2]Abandoned quarries or wayside quarries operating on demand under authority of a permit.

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, TOWNSHIP OF ZORRA.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
Lucas Formation **Detroit River Group**							
1	25-50 (8-15)	1100 (445)	400 (162)	0 (0)	700 (285)	100 (30)	250 (227)
	50-100 (15-30)	11,300 (4550)	1060 (430)	0 (0)	10,200 (4150)	100 (30)	3650 (3300)
		12,400 (5000)	1460 (590)	0 (0)	10,900 (4400)		3900 (3550)

TABLE 7. SUMMARY OF TEST HOLE DATA, TOWNSHIP OF ZORRA.

-NONE-

TABLE 8. SUMMARY OF GEOPHYSICS DATA, TOWNSHIP OF ZORRA.

-NONE-

TABLE 9. AGGREGATE QUALITY TEST DATA, TOWNSHIP OF ZORRA.

-NONE-

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g. "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 35 to 60 feet (11 to 18 m) near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 40 to 72 feet (12 to 22 m) thick in the east and the remainder of the formation is 40 feet (12 m). Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 9 to 200 feet (3 to 61 m). Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 60 to 160 feet (18 to 49 m). Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Member A: thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone with a maximum thickness of 60 feet (18 m). Members B and C are dense, aphanitic limestones with argillaceous dolostone interbeds. Uses: Quarried at Kirkfield and Uhthoff for crushed stone. The product is generally fresh and compact with good cubic-shaped factor, low clay content, low absorption, and low soundness losses. Smooth particle surfaces may cause adhesion problems for asphalt. There is some alkali reactivity in a few of the layers.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone.

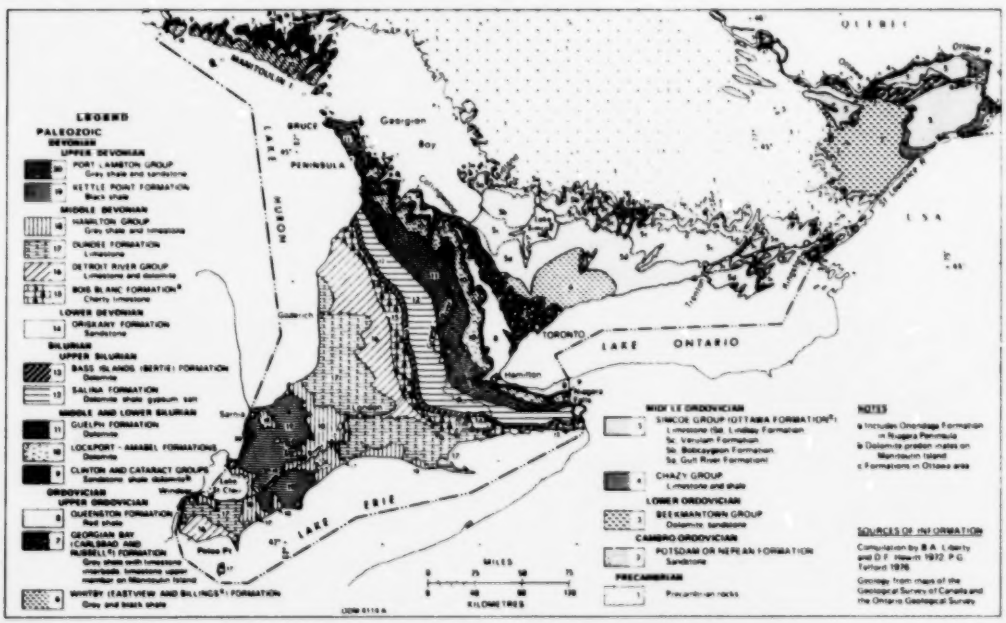

Figure 2. Bedrock Geology of Southern Ontario.

Thickness: Amabel Formation: maximum observed thickness of 84 feet (26 m). Lockport Formation: up to 130 feet (40 m). Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey-brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

Ottawa Formation (Middle Ordovician)

Composition: Lower Phase (Lowville and Pamela Beds): shale, some sandstone and dolostone. Thickness: 100 feet (30 m). Middle Phase (Hull, Rockland, and Leray Beds): pure, thick-bedded, crystalline limestone. Thickness: 150 feet (46 m) near Ottawa. Upper Phase (Cobourg and Sherman Fall Beds): pure and impure crystalline limestone with few to numerous shaly partings, 450 to 475 feet (137 to 145 m) thick near Ottawa. Uses: The Leray, Rockland, and Hull Beds have been quarried extensively for crushed stone and for building stone. In addition, the Hull Beds are an excellent source of limestone for cement production and agricultural uses.

Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 240 feet (73 m). Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to microcrystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 100 feet (30 m) at Beachville, 350 feet (107 m) at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 100 to 170 feet (30 to 52 m). Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 200 to 300 feet (61 to 91 m). Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas) Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 640 feet (195 m) at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 80 to 300 feet (24 to 91 m). The Arkona Formation has a thickness of 14 to 121 feet (4 to 37 m). Uses: The

Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 400 to 500 feet (122 to 152 m). Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

Salina Formation (Upper Silurian)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

Blue Mountain Formation (Upper Ordovician)

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation and Communications on sampled material. A description of each test is found in Appendix B while the specification limits for each test are included in this Appendix in Table E1. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this Appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications.

TABLE E-1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness - Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	-	-	60	-
16 mm Crushed Type 'A'	160	-	-	35	-
16 mm Crushed Type 'B'	200	-	-	60	-
Granular Subbase B	250	-	-	-	-
Granular Subbase C	250	-	-	-	-
Granular Subbase D	-	-	-	-	-
Hot Mix - H. L. 1	100	5	1.0	15	16
Hot Mix - H. L. 2	-	-	-	-	20
Hot Mix - H. L. 3	135	12	1.75	35	16
Hot Mix - H. L. 4	160	12	2.0	35	20
Hot Mix - H. L. 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(M.T.C. Forms 1002, 1003 and 1010)

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.

Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.

Test hole data from Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Northern Development and Mines.

Selected drilled water well data from the Ontario Ministry of the Environment.

Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.

Geology by P.J. Barnett, 1982.
W.R. Cowan, 1975.
P.F. Karrow, 1971, 1977.
E.V. Sethi and U.J. Vagners, 1975.

Compilation and Drafting by Staff of the Aggregate Assessment Office.
Additional Fieldwork by: Staff of the Aggregate Assessment Office.
This map is to accompany O.G.S. Aggregate Resources Inventory Paper 61.

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Issued 1986.

Information quoted for an individual test hole or pit refers to a specific sample or face. Care should be exercised in extrapolating such information to other parts of the deposit.

Ministry of Northern Development and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF ZORRA

OXFORD COUNTY

MAP 1
DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

Scale 1:50 000

NTS Reference 40 1/15, 40 P/2, 40 P/3, 40 P/6, 40 P/7

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Location Map

Scale: 1 : 1 800 000

SYMBOLS

(Some symbols may not apply to this map.)

- Township boundary.
- Project area boundary.
- Geographic township within township boundary.
- County, District, Regional or District Municipal boundary.
- City or town limits.
- Park, reserve boundary.
- Geological and aggregate thickness boundary of sand and gravel deposits.
- Buried geological and aggregate thickness boundary of sand and gravel deposits.
- Licenced property boundary; Property number: see Table 2.
- Unlicenced sand or gravel pit*, Property number: see Table 2.
- *Abandoned pit or wayside pit operating on demand under authority of a permit.
- Test hole location; Identification number: see Table 7.
- Selected sample site; Identification number: see Figure 5.
- Geophysical traverse line; Identification number: see Table 8.
- Selected water well location. Layers of materials are described by: reported thickness of material (in feet); reported type of material (number only - overburden; G - gravel, S - sand, C - clay, T - till, B - boulders, Bk - bedrock, Hpan - hardpan, Stn - stones, Silt - silt).
- Texture symbol: see below.
- Deposit Symbol: see below.

TEXTURE SYMBOL

(This symbol is used where sample analysis data are available.)

Fines: silt and clay (< .075 mm)

Gravel (> 4.75 mm)

Sand (.075 - 4.75 mm)

The Texture Symbol provides quantitative assessment of the grain size distribution at a sampled location. The relative amounts of gravel, sand, silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The above example shows a hypothetical sample consisting of 45% gravel, 35% sand and 20% silt and clay.

DEPOSIT SYMBOL

Gravel Content — Geological Type

Thickness Class — Quality Indicator

Deposits are identified by Gravel Content, Thickness Class, Geological Type and Quality Indicator. Gravel Content is expressed as a percentage of gravel-sized material (i.e. material retained on the 4.75 mm sieve). Thickness Class is based on potential aggregate tonnage per acre. Geological Type refers to geologic origin. Quality Indicator describes objectionable grain size and lithology.

Gravel Content

G	Greater than 35% gravel.
S	Less than 35% gravel.

Thickness Class

Class	Average Thickness in feet (metres)	Tons per acre (Tonnes per hectare)
1	greater than 20 (> 6)	greater than 50,000 (> 112 000)
2	10-20 (3-6)	25,000-50,000 (56 000 - 112 000)
3	5-10 (1.5-3)	12,500 - 25,000 (28 000 - 56 000)
4	less than 5 (< 1.5)	less than 12,500 (< 28 000)

Geological Type

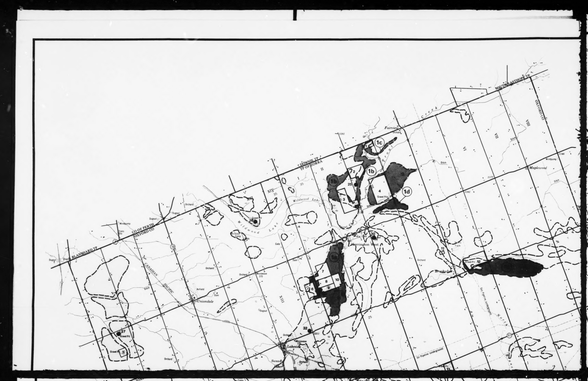
AL	Alluvium	K	Kame
I	Esker	LB	Lacustrine Beach
EM	End Moraine	LD	Lacustrine Delta
IC	Undifferentiated Ice Contact Stratified Drift	LP	Lacustrine Plain
ICT	Ice-Contact Terrace (see Appendix C for descriptions of Geological Types)	OW	Outwash
		WD	Windblown Forms

Quality Indicator

If blank, no known limitations present.

C	Clay and or silt (fines) present in objectionable quantities.
L	Deleterious lithologies present.
O	Oversize particles or fragments present in objectionable quantities.

ZORRA



Ministry of Northern Development and Mines
Ontario

ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF ZORRA

OXFORD COUNTY

MAP 2
SELECTED SAND AND GRAVEL RESOURCE AREAS

Scale 1 : 50 000

NTS Reference: **40 I/15, 40 P/2, 40 P/3, 40 P/6, 40 P/7**

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Location Map — Scale 1:1 800 000

LEGEND
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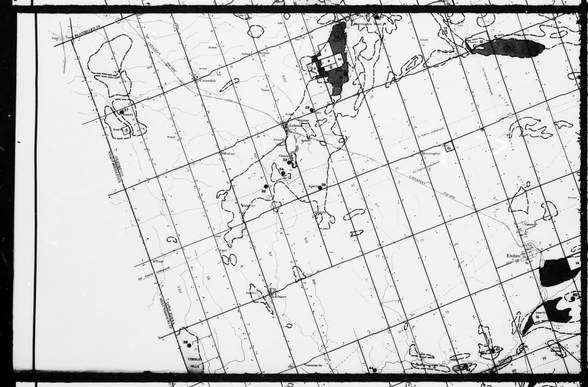

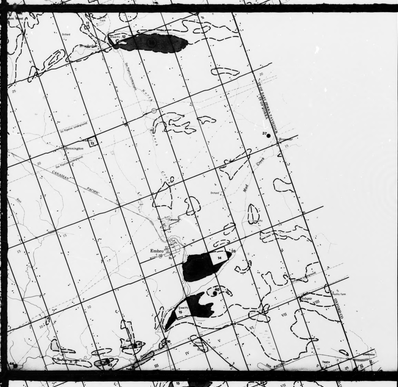

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Location Map — Scale 1:1 800 000

LEGEND
(Some map units and symbols may not apply to this map.)

MAP UNITS

- Selected sand and gravel resource area, primary significance; deposit number; see Table 3.
- Selected sand and gravel resource area, secondary significance.
- Selected sand and gravel resource area, tertiary significance.

SYMBOLS

- Township boundary.
- Project area boundary.
- Geographic township within township boundary.
- County, District, Regional or District Municipal boundary.
- City or town limits.
- Park, reserve boundary.
- Geological and aggregate thickness boundary of sand and gravel deposits.
- Buried geological and aggregate thickness boundary of sand and gravel deposits.
- Licensed property boundary; Property number; see Table 2
- Unlicensed sand or gravel pit*; Property number; see Table
- *Abandoned pit or quarry/pit or quarry/pit on stand-by or operating on demand under authority of a permit.

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
Licence data from District and Regional Offices, Ontario Ministry of Natural Resources.
Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Geology by: P.J. Barrett, 1982
M.R. Cowan, 1975.
F.F. Karrow, 1971, 1977.
E.V. Sahi and J.J. Haynes, 1975.

Correlation and Drafting by: Staff of the Aggregate Assessment Office.
Additional Fieldwork by: Staff of the Aggregate Assessment Office.
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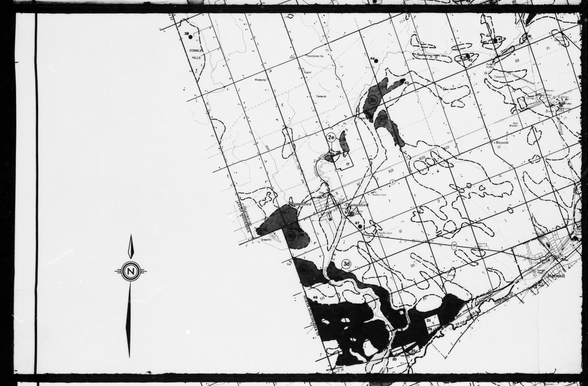

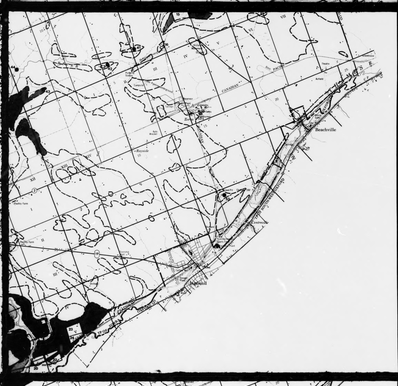

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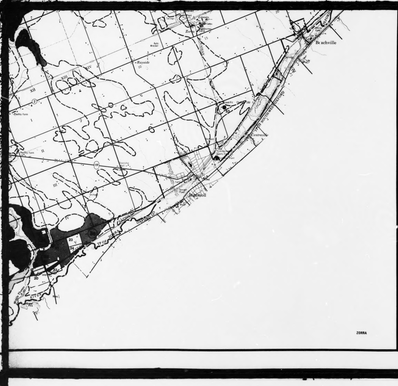

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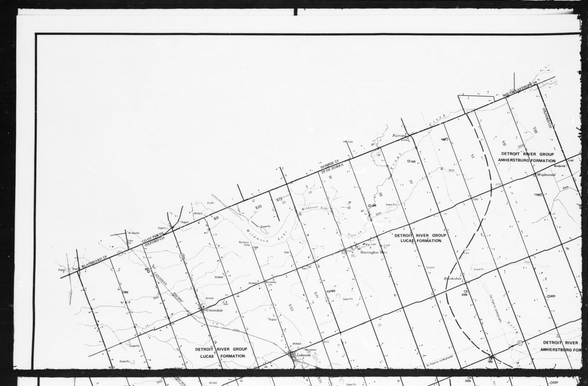

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ONTARIO GEOLOGICAL SURVEY
AGGREGATE RESOURCES INVENTORY

TOWNSHIP OF ZORRA

OXFORD COUNTY

MAP 3
BEDROCK RESOURCES

Scale 1 : 50 000

NTS Reference: **40 I/15, 40 P/2, 40 P/3, 40 P/6, 40 P/7**

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Location Map — Scale 1:1 800 000

LEGEND
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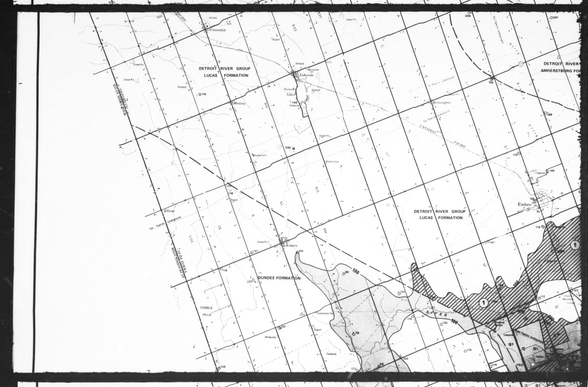
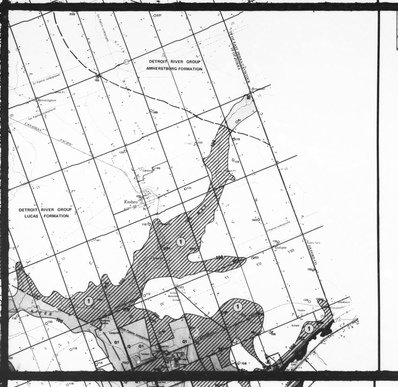
BEDROCK UNITS





Location Map — Scale 1:1 800 000

LEGEND
(Some map units and symbols may not apply to this map.)

BEDROCK UNITS

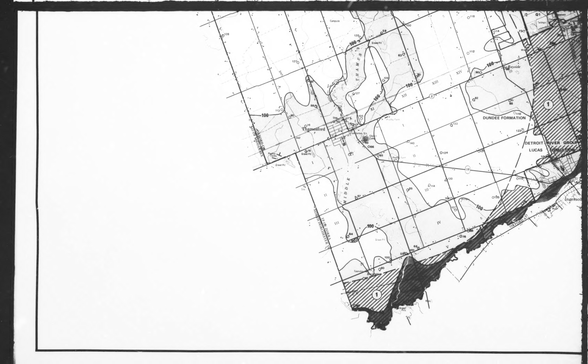
PALEOZOIC
DEVONIAN
MIDDLE DEVONIAN
DUNDEE FORMATION
Limestone
DETROIT RIVER GROUP
LUCAS FORMATION
Limestone
AMHERSTBURG FORMATION
Limestone and dolostone

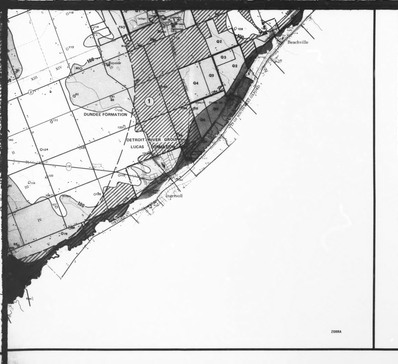
DRIFT THICKNESS

- Bedrock covered by drift; see Table 8; drift thickness is generally 3 to 30 feet (1 to 10m). Bedrock outcrops may occur.
- Bedrock covered by drift; see Table 8; drift thickness is generally 30 to 100 feet (10 to 30m). Isolated bedrock outcrops may occur.
- Bedrock covered by drift; drift thickness is generally greater than 100 feet (30m); see Table 8.
- Bedrock covered by drift; drift thickness is generally greater than 199 feet (60m).

SYMBOLS

- Township boundary.
- Project area boundary.
- Geographic township within township boundary.
- County, District, Regional or District Municipal boundary.
- City or town limits.
- Park, reserve boundary.
- Geological formation boundary.





2599A

- Park, reserve boundary.
- Geological formation boundary.
- Geological formation member boundary.
- Formation thickness boundary (see text).
- 25 — Drift thickness contour; 050 - feet and 100 - foot contours are shown).
- Selected bedrock resource area; deposit number; see Table 6.
- Licensed quarry boundary; Property number; see Table 5.
- Unlicensed quarry*; Property number; see Table 5.
  *Abandoned quarry or exposite quarry operating on demand under authority of a permit.
- Isolated bedrock outcrop.
- Selected water well location, reported depth to bedrock (in feet).

SOURCES OF INFORMATION

Base map by Surveys and Mapping Branch, Ontario Ministry of Natural Resources.
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Aggregate suitability data from the Engineering Materials Office, Ontario Ministry of Transportation and Communications.
Selected water well data from the Ontario Ministry of the Environment.
Drilling data from the Petroleum Resources Section, Ontario Ministry of Natural Resources.
Geology by: P.J. Barrett and A.L. Sharkoski, 1978.
F.F. Karrow, L.L. Dorris and W.A. McClymont, 1962.
F.F. Karrow and A.J. Ferguson, 1975.
M.R. Cowan, 1975, 1986.
E.V. Sanford, 1963.

Compilation and Drafting by: Staff of the Aggregate Assessment Office.

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